Fermi National Accelerator Laboratory

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E710

Status of Fermilab E710

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STATUS OF FERMILAB E-710

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Abstract

This report give the current status of E-710, an experiment at the Fermilab $\bar{p}p$ Tevatron Collider to measure elastic scattering, total cross sections and diffraction dissociation up to $\sqrt{s} = 1.8$ TeV.

Among the goals of E-710 are measurement at the highest available energy of the elastic scattering t distribution to see if there are dips, and to see if the distribution is more complex than a single exponential; to study the s dependence of the total cross section; to study single diffraction dissociation, where lower energy data showed considerable inconsistency; to measure ρ (the ratio of the real to imaginary part of the forward scattering amplitude). Prior to this experiment, the UA4 experiment at CERN had measured ρ at $\sqrt{s}$ = 546 GeV and had obtained a result which was about 2.5 standard deviations from the expected value obtained from lower energy data. New physics phenomena were invoked to explain this result. Analysis of the E-710 data is still under way, and this report covers all available up to the time of the V[th] Blois Workshop. (Information on other experiments is referenced only if available prior to the V[th] Blois Workshop.)

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The experimental layout is shown in Figure 1. Elastic scattering events are recorded using 8 drift chamber/scintillator assemblies in "Roman Pots"; the detectors can be moved to within 2.2 mm of the center of the circulating proton and antiproton beams in order to measure small $|t|$ elastic scattering (down to $|t| = 0.0007$ (GeV/c)^2 at $\sqrt{s} = 1.8$ TeV). There are a series of annular counters and drift chambers around the Tevatron beam pipe which record particles emitted in inelastic collisions.

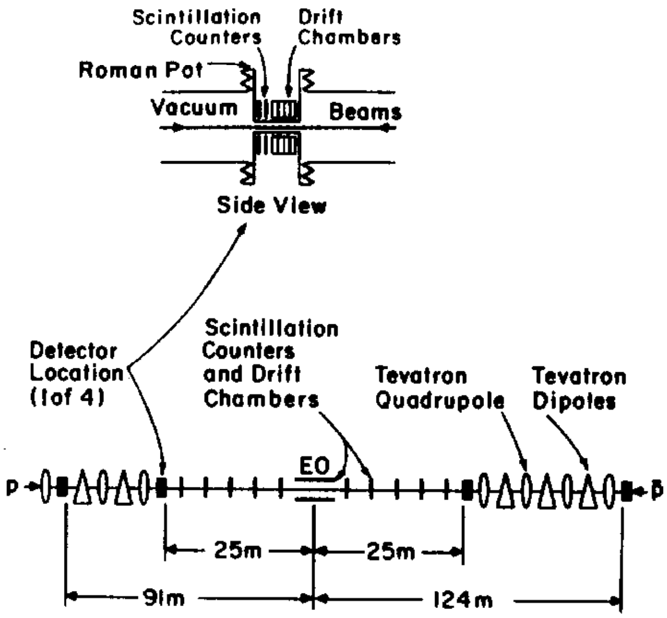

Figure 1

After selection of elastic events and subtraction of background, we use the following expression for the elastic differential cross section:

$$\frac{1}{L}\frac{dN_{el}}{dt} = \frac{d\sigma}{dt} = \frac{4\pi\alpha^2(\hbar c)^2 G^4(t)}{|t|^2} + \frac{\alpha(\rho - \alpha\phi)\sigma_T G^2(t)}{|t|}\exp(-B|t|/2)$$

$$+ \frac{\sigma_T^2(1+\rho^2)}{16\pi(\hbar c)^2}\exp(-B|t|). \qquad (1)$$

The three terms in Eq. (1) are due to, respectively, Coulomb scattering, Coulomb-nuclear interference, and nuclear scattering. L is the integrated accelerator luminosity, dN_{el}/dt is the observed elastic differential distribution, α is the fine structure constant, ϕ is the relative Coulomb-nuclear phase, given by

$$\ln(0.08|t|^{-1} - 0.577),$$

and $G(t)$ is the nucleon electromagnetic form factor, which we parametrize in the usual way as $(1+|t|/0.71)^{-2}$ [t is in $(\mathrm{GeV}/c)^2$)]. Note that there is the conventional assumption in Eq. (1) that the elastic distribution is an exponential in $|t|$ down to $t=0$.

We also use the following two equations:

$$\sigma_T^2 = \frac{1}{L}\frac{16\pi(\hbar c)^2}{1+\rho^2}\left.\frac{dN_{el}^n}{dt}\right|_{t=0} \tag{2}$$

$$\sigma_T = \frac{1}{L}(N_{el}^n + N_{inel}) \tag{3}$$

Eq. (2) is obtained from the optical theorem. N_{el}^n is the total number of nuclear elastic events, obtained from the observed dN_{el}/dt distribution in the t region where nuclear scattering dominates, and extrapolated to $t=0$ and $t=\infty$ using the form $\exp(-B|t|)$. $dN_{el}^n/dt|_{t=0}$ is the observed differential number of nuclear elastic events extrapolated to $t=0$ using the same form. N_{inel} is the total number of inelastic events obtained from the inelastic counters.

Using Eq. (2), σ_T can be derived from elastic data, but with an error dominated by the ±15% uncertainty in the accelerator luminosity L. This was used at $\sqrt{s}$ = 1020 GeV. At $\sqrt{s}$ = 1.8 TeV, Eqs. (2) and (3) were combined to obtain a more accurate value of σ_T, independent of L.

Figure 2 shows the elastic distribution obtained at $\sqrt{s}$ = 1.8 TeV. Unlike at lower energies, the data are consistent with a single slope parameter

$$(b \approx 17\ (\mathrm{GeV}/c)^{-2})$$

across all of the t range studied. At lower energies b decreases as a function of t, while for a black disk, b increases as a function of t. Thus if the nucleon is becoming blacker as a function of energy, and will eventually approach a black disk, there will be an intermediate energy where b should be independent of t, as we observe.

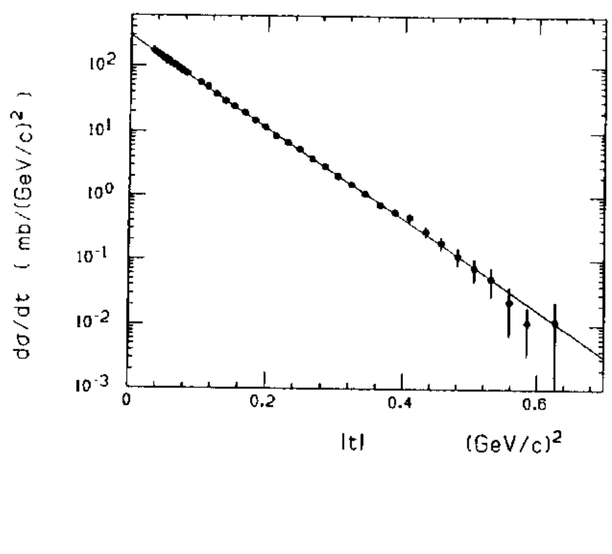

Figure 2

Figure 3 shows σ_T as a function of $\sqrt{s}$. The total cross section continues to increase with energy, although the dependence at the highest measured energies appears to fit $\log s$ somewhat better than $\log^2 s$. Our values of σ_T, as well as σ_{el} and b, agree with those obtained by CDF as given at the IVth Blois Workshop.

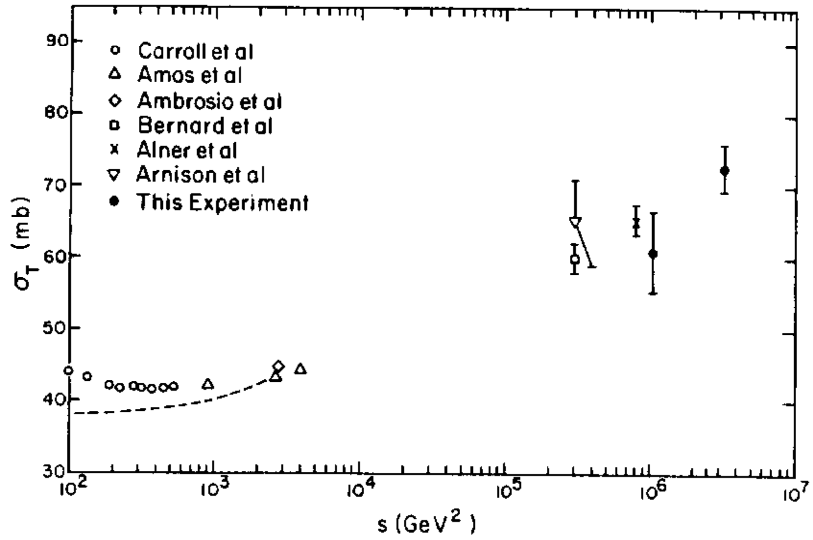

Figure 3

In Figure 4 we give the ratio σ_{el}/σ_T as a function of s. As s increases from ISR energies, this ratio rises, showing that the nucleon is becoming blacker as energy increases, although the ratio has not yet reached the black disk value of 0.5. This is consistent with the conclusion drawn above from the elastic t distribution of Figure 1.

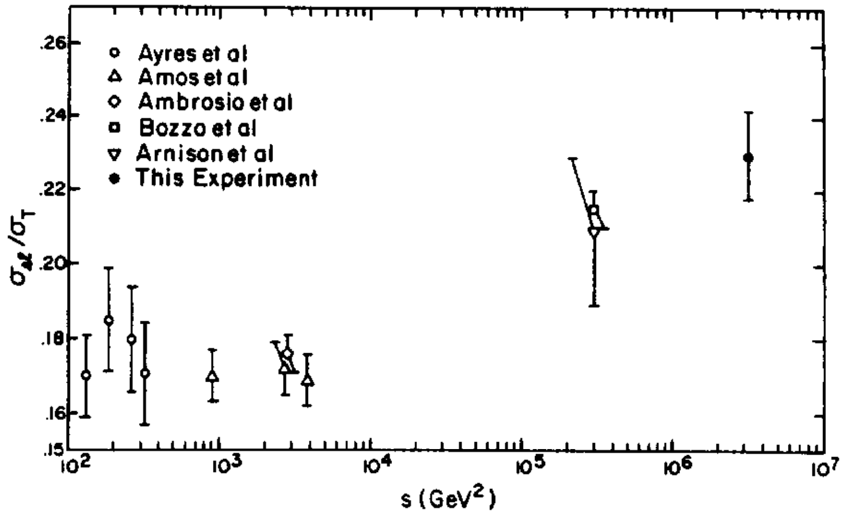

Figure 4

Our value for ρ at $\sqrt{s}$ = 1.8 TeV is shown in Figure 5, together with lower energy data. As can be seen, our result agrees with the curve predicted based from the lower energy data (excluding the $\sqrt{s}$ = 546 GeV measurement), and thus requires no new physics.

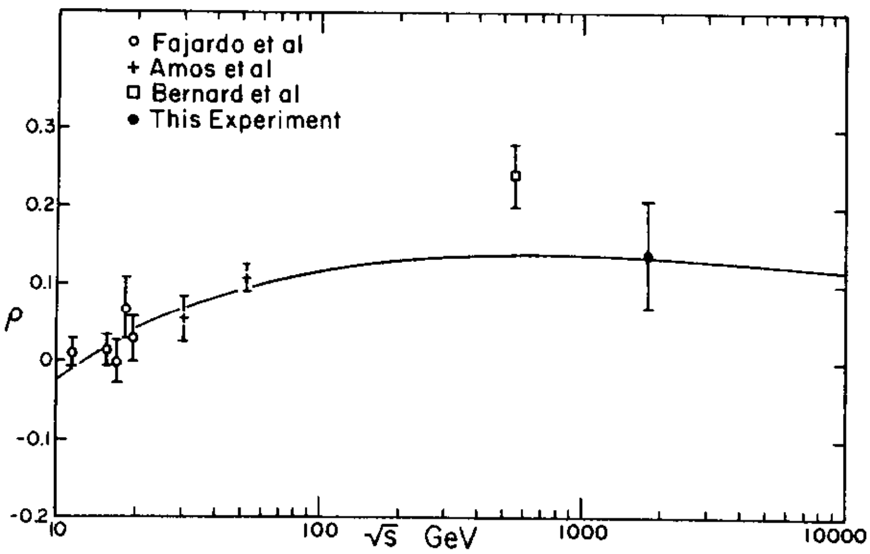

Figure 5

We have studied single diffraction dissociation at $\sqrt{s}$ = 1.8 TeV, using two different methods. In the first, we use an experimental definition of diffraction suited to our experimental arrangement. A diffractive event is one where no inelastic counter one side of the interaction point is hit, while $\geq$ 1 hits are recorded on the other side (see Figure 1). The assumption is that the outgoing antiproton from the reaction $\bar{p}p \to \bar{p}x$ (or the outgoing proton from $\bar{p}p \to px$) is scattered at a very small angle and does not emerge from the beam pipe, while one particle from x hits an inelastic counter on the other side. Extrapolations are required to take into account regions not covered by the counters, and corrections for single arm events that would be double arm if there were full 4π coverage. In addition, there is a correction for the case where x decays into particles which reach detectors on both sides. Our result is that $2\sigma_{SD} = 11.7 \pm 2.3$ mb (the conventional factor of 2 is used to denote that the value includes diffraction of both the proton and the antiproton, which are assumed to be equal).

In the second method, we require the outgoing antiproton to be registered in Roman Pot detectors at both the 25 meter and 91 meter locations from the interaction point, which allows its momentum to be determined. In addition, at least one particle has to be registered in a subset of the inelastic counters on the other side of the interaction point. The antiproton momentum allows determination of M_X, the mass of the outgoing particles on the proton side.

We use the usual parametrization

$$d\sigma/dt\, dM_X^2 = Af(t)\, g(M_X^2) \qquad (4)$$

with $f(t) = e^{bt}$; $g(M_X^2) = (M_X^2)^{-\alpha}$.

$2\sigma_{SD}$ is obtained by integration of Eq. (4) with the limits $0 \leq |t| \leq \infty$ and

$$2\ \mathrm{GeV}^2 \leq M_X^2 \leq 0.05s.$$

Figure 6 shows the correlation in x (horizontal, bend plane) of the antiproton at the 2 recording stations. Events to the right of the central peak have an antiproton momentum greater than elastic, and so $M_X^2 < 0$; those to the left are diffractive events with momentum less than elastic, and $M_X^2 > 0$.

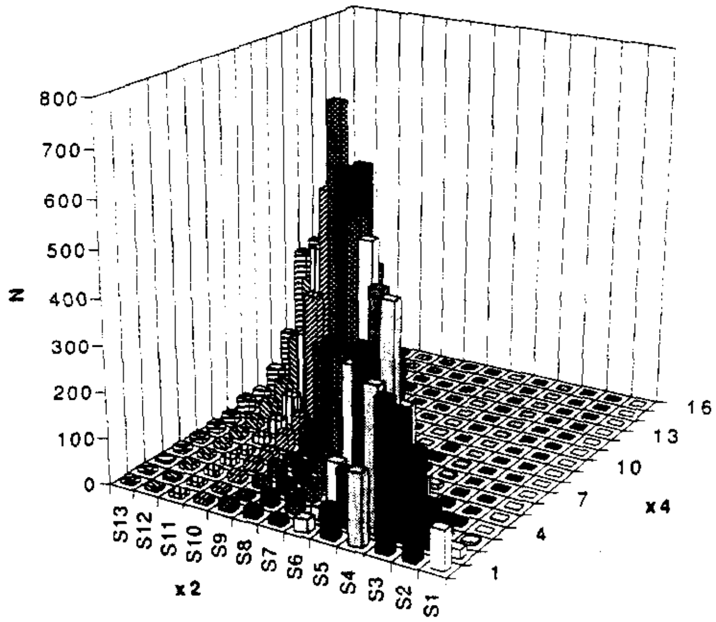

Figure 6

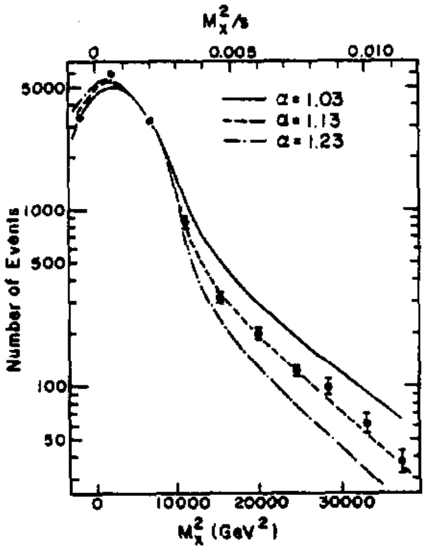

Figure 7

In Figure 7 we show our experimental M_X^2 distribution together with Monte Carlo generated curves for 3 different values of α.

Our final results are:

$$b = 10.5 \pm 1.8\ (\mathrm{GeV}/c)^{-2}; \quad \alpha = 1.13 \pm 0.07; \quad 2\sigma_{SD} = 8.1 \pm 1.7\ \mathrm{mb}$$

We note that b is about half of the value for elastic scattering [17 $(GeV/c)^{-2}$], as found at lower momenta, and the M_X dependence is close to M_X^{-2} as is also found at lower momenta. There is some indication that b may be a function of M_X (i.e. Eq. (4) is not a good parametrization), but our statistics do not allow a definitive statement. The values of $2\sigma_{SD}$ obtained by our two different methods are shown in Figure 8; they are consistent. It is difficult to draw conclusions about the energy dependence of $2\sigma_{SD}$ because different experiments use different definitions of diffraction dissociation; however the data are consistent with a slow increase of $2\sigma_{SD}$ with energy at roughly the same rate as the $\bar{p}p$ total cross section.

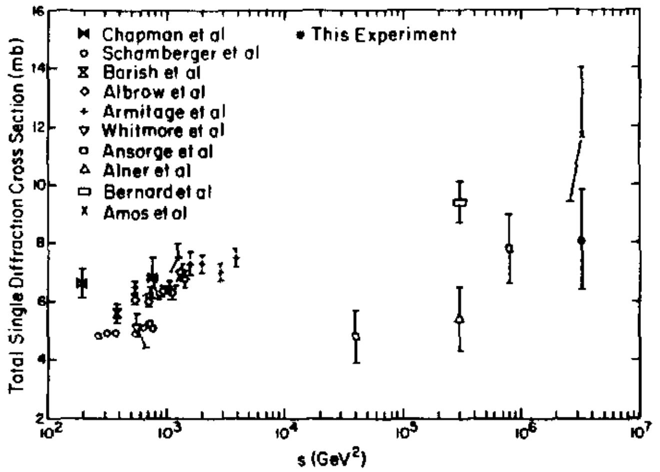

Figure 8

Summary

1. The nucleon is becoming blacker as energy increases. The evidence is the increasing value of σ_{el}/σ_T and the lack of curvature in the elastic scattering t distribution at $\sqrt{s}$ = 1.8 TeV.

2. The $\bar{p}p$ total cross section continues to rise with energy, approximately as $\log s$.

3. The measurements of σ_T and ρ at $\sqrt{s}$ = 1.8 TeV do not require any new physics.

4. Single diffraction has M_x and t distributions as expected from lower energy data. Allowing for differences in experimental techniques, the total single diffraction cross section is slowly rising with increasing energy.

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